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Final Report for

A FOCUSED RESEARCH PROGRAM IN OCEANIC MASS FLUX
(NASA Grant NAGW-1191)

1 Introduction

This report covers the work done under NASA grant NAGW-1191 supporting "A Focused Research Program in Oceanic Mass Flux" at the Colorado Center for Astrodynamics Research (CCAR). This project was originally funded as two separate projects. The original grant NAGW-1191 was in support of "A Multidisciplinary Precipitation Research Program in Support of the Earth Observing System (Eos)". This was combined with grant NAGW-1754 which supported "Statistical Intercomparison and Verification of SSM/1 Oceanic Precipitation Algorithms and System Testing: A WetNet Core Project". The funding for these two projects was combined in 1989 and was continued as a single research program. This report attempts to differentiate the work and equipment which was funded in the early stages of this project as being either part of the Eos research project or the WetNet project.

2 Active Data Base

When Dr. Chase arrived at CCAR, there existed only a Pyramid computer to meet the computation, visualization, and archival requirements for building the active data base and performing oceanic mass flux studies. This computer system was inadequate to meet the needs of the proposal and a new distributed network imaging facility was built.

The distributed computing facility is based on the Sun Microsystems (Sun) workstations and consists of a Sun 3/280 server with two 850 megabyte drives, one Floating Point accelerator board, one 1/2 inch tape drive, a Texas Instruments Omni laser printer, a Tektronix thermal transfer printer for hardcopy color output, and two Genesis Optical disk drives. Two Sun 3/50 workstations with monochrome monitors and two 3/60 workstation with a color monitor are also attached to the 3/280 server.

The optical drives provide 3.6 gigabytes of data storage per platter to support multi-spectral satellite data archiving. At present, the ESS group has archived 2 years of SSM/1 data from July of 1987 through June of 1988 as well as a variety of ancillary data.

Also on the network is a Sun 4/260 (SPARC cpu) with 32 megabytes of internal memory, two 260 megabyte disk drives, one 1/4 inch tape drive, and a color monitor.

To enhance visualization, the network has on permanent loan from Mobil Oil Corporation, Dallas Research Laboratory, the Trancept Applications Accelerator board (TAAC-1) manufactured by Sun.

The TAAC-1 is a two-board hardware expansion that fits into the backplane of the Sun 4/260 workstation. It is a unique volumetric visualization tool allowing the user to display a 32 bit image, (8 bits for red, green, blue, and alpha), on the native monitor windowing system or on a separate monitor. User application software for the TAAC-1 is built around the C language. Sun has provided a volume rendering software toolkit to allow the user to visualize a volume data set. We have modified this software to allow our data to be easily entered into and extracted from the TAAC-1 and to display time-varying satellite and in-situ data.

In support of the WetNet project, eleven IBM PC's were purchased and distributed to scientists in the university community. These machines were configured in the CCAR lab and distributed to the WetNet scientists.

Several papers have been written regarding the development of the active data base and are included with the report. A complete list and description of the equipment purchased under this grant is also included at the end of this report.

3   Results from Scientific Investigations

Several different scientific investigations were pursued during the course of this four year grant. As discussed previously, the implementation and analysis of an active data base for performing the scientific investigations was a critical component to all of the research efforts.

A significant amount of work has done on determining the optimal orbit characteristics for studying large-scale features from satellites. The paper by Chase and Mundt (1989) concentrates on such an orbit optimization for using satellite altimetry to study the global oceanic mesoscale. In addition, the paper by Chase and Maguire (1990) looks at determining ground trace crossovers for multiple spacecraft, which is necessary for using multiple satellites to observe highly variable processes such as rainfall.

Another research project funded by this grant is the study of rainfall over the tropics using satellite data. A paper by Berg and Chase (1990) details the process of computing mean oceanic rainfall for monthly to annual time periods and gives results over a one year period using data from the Special Sensor Microwave/Imager (SSM/I). The time integrated rainfall was computed by fitting the instantaneous rainfall estimates over the specified time period to a mixed lognormal distribution. Verification of both the instantaneous and time integrated rainfall estimates have been made using in situ rain gauge and radar data. Current results have primarily focused on the use of the Hughes D-matrix algorithm to compute the instantaneous rainfall estimates. However, comparisons with other algorithms, including one developed by Roy Spencer at Marshall and another developed by William Olson at the University of Wisconsin, have been conducted in order to determine the best available algorithm for studying tropical oceanic rainfall.

Progress has also been made in developing new techniques for analyzing the resulting data. The ability to make high speed color visualizations of large data sets is an excellent tool for observing the time dependent behavior of rainfall. In addition, tools for analyzing the resulting three dimensional data volumes provide unique new opportunities for investigating the temporal variability of rainfall and other geophysical parameters over large spatial regions. The application of these techniques to the analysis of space debris is detailed in the paper by Luetkemeyer et al. (1990), and a paper describing the application of volumetric analysis techniques to Earth System Science is currently being prepared.

Finally, the application of chaos theory to understanding and predicting geophysical and other processes has been investigated. The paper by Mundt et al. (1990) has applied this technique to predicting the sunspot cycle. This has also led to further investigations into the use of such techniques towards predicting ocean variability.

Additional work has been done in cooperation with the WetNet community in several areas of scientific investigation. The ability for interaction between the PC McIDAS, which was installed on the IBM PC's for the WetNet program, and the active data base has also been pursued. PC McIDAS was installed on our IBM PC and used to analyze a variety of data sets. In addition, modifications to McIDAS were implemented for our specific needs. Through attendance at the WetNet training session and subsequent experimentation with the software, we have been able to effectively use the system for the analysis of SSM/I data and have successfully integrated the WetNet system with our active data base. We developed software for transferring data back and forth between the PC and our active data base as well as for transferring McIDAS images to our color thermal transfer printer.

The scientific investigations supported by this research grant have resulted in a number of publications as well as numerous new ideas and advances. The active data base purchased from this grant has made much of the research possible and continues to provide an advanced tool for remote sensing studies. We greatly appreciate the research opportunities which this grant provided, and we hope to continue to expand on these research areas.

3

Listing of Hardware purchased under this contract:

I. **Sun Microsystems**
   1. (1) 3/280 workstation
      with 8 megabytes of memory,
      (1) floating point accelerator board ,
      (1) additional EtherNet controller board
      (2) Fujitsu 850 megabyte disk drives,
      (1) Fujitsu 1/2 inch tape drive,
   2. (2) 3/50 workstations with monochrome monitors,
   3. (2) 3/60 workstation with a color monitor,
   5. (1) 4/260 workstation with a color monitor and
      32 megabytes of internal memory,
      (2) Fujitsu 260 megabyte drives,
      (1) Fujitsu 1/4 inch tape drive,

II. **Texas Instruments**
   1. (1) Omni Laser Printer

III. **Tektronix**
   1. (1) 4693 Color Thermal Transfer Printer

IV. **Genesis**
   1. (1) Sony optical controller
   1. (2) Sony Optical disk drives
      containing 1.8 gigabytes per platter side

V. **IBM**
   1. (11) PS/2

List of Publications

Chase, Robert R.P., 1988: A User's Perspective of the Eos Data and Information System, *Geosci. and Rem. Sen. Soc. Newsletter*, 12(3), 15–17.

Chase, R., 1989: Toward a Complete Eos Data and Information System, *J. Geosci. Remote Sensing*, 27(2), 125–131.

Chase, R. and M. Mundt, 1989: Optimized Orbits for the Constellation of Space Station Platforms, *Advances in the Astronautical Sciences*, Edited by Robert D. Culp and Robert A. Lewis, Proc. Amer. Astronaut. Soc., 185–203.

Chase, R. and F. Ziel, 1989: On Developing the Local Research Environment of the 1990's: the Space Station Era, *Advances in the Astronautical Sciences*, Edited by Robert D. Culp and Robert A. Lewis, Proc. Amer. Astronaut. Soc., 171–184.

Chase, R. and M. Mundt, 1989: On Optimizing a Constellation of Altimetric Satellites for Measuring Global Oceanic Mesoscale, *J. Astronaut. Sci.*, 37(4), 477–489.

Chase, R., F. Ziel and K. Luetkemeyer, 1990: Evolution of an Active Data Base: Toward Developing the Local Research Environment of the 1990's, *IEEE Trans. Geosci. and Remote Sensing*, 28(1), 146–148.

Luetkemeyer, K., T. Maclay, R. Madler and R. Culp, 1990: Volumetric Imaging of Space Debris using Sun Microsystem's TAAC-1 Application Accelerator Board, *AIAA/AAS Astrodynamics Technical Papers*, Paper 90-2977, 847–856.

Chase R. and W.B. Maguire, 1990: Determining Ground Trace Crossovers for Multiple Spacecraft, *Acta Astronautica*, 21(8), 535–544.

Mundt, Michael D., W. Bruce Maguire II and Robert R.P. Chase, 1991: Chaos in the Sunspot Cycle: Analysis and Prediction, *JGR–Space Physics*, 96, 1705–1716.

Berg, Wesley and Robert Chase, 1990: Determination of Mean Rainfall from the Special Sensor Microwave/Imager (SSM/I) using a Mixed Lognormal Distribution, *J. Atm. Oceanic Tech.*, (accepted pending revisions)

Thesis

Allen, Patrick Charles, 1991: "An Altimetric Study on the Branching of the Gulf Stream System into the North Atlantic and Azores Currents", 98 pages.